

COMPANIONS OF QSOs AT REDSHIFT 1.1

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ABSTRACT

We discuss broad- and narrow-band imaging of 7 arcmin fields of 14 QSOs with redshift ~ 1.1 . The narrow-band filters were chosen to detect redshifted [O II] 3727Å, and the broad bands are R and I, which correspond to rest wavelengths ~ 3300 Å and ~ 3800 Å. In 100 arcsec subfields surrounding the QSOs, we detect an excess of typically 15 detected objects over the background of 25. Several of the QSO subfields also contain an excess of blue ($R-I < 1.0$) galaxies compared with the other subfields. Finally, several of the QSO subfields contain an excess of galaxies with significant narrow-band flux compared with the other subfields, and many of these are also blue. Most of the QSOs are radio-quiet in a region of sky overpopulated with $z=1.1$ QSOs, and 3 others are radio-loud from other parts of the sky. We suggest that most of these $z=1.1$ QSOs are in compact groups of starbursting galaxies. In our data, there is no significant difference between radio-loud and radio-quiet QSOs. We discuss cosmic evolutionary implications.

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1. INTRODUCTION AND MEASUREMENTS

In Hutchings, Crampton and Persram (1993:HCP), we discussed results from an imaging program to detect companions to QSOs, using broad-band and also narrow-band (NB) filters tuned to strong emission lines at the QSO redshift. We described two fields in some detail at $z \sim 1.1$, and initial results from several others. The principal result was that we find evidence for an excess of faint galaxies within ~ 1 arcmin of the QSO, and that among these there is an excess of blue galaxies and emission-line candidates, compared with other parts of the 7 arcmin fields. The faint galaxy magnitudes are consistent with bright galaxies at the redshift of the QSO, but their blue colour at this redshift can only arise if they are starburst objects. The suggestion from these results is that the QSOs are in compact groups or clusters of star-forming galaxies. Such a conclusion may have significant implications for galaxy formation, and cluster evolution. We also note that early results from the Keck telescope and other recent investigations (Matthews et al 1994, Soifer et al 1994, Graham et al 1994, Giavalisco, Steidel and Szalay 1994), are also finding imaging evidence of clusters around active galaxies at even higher redshifts. Dressler et al (1993) report on a possible cluster at $z \sim 2.0$ from HST imaging.

We present here the details of the whole sample at $z = 1.1$, including one further object observed with the High Resolution Camera of the CFHT. We have 11 radio-quiet QSOs from the region studied by Crampton, Cowley and Hartwick (1989), and 3 radio-loud QSOs from elsewhere in the sky. The main program was observed with FOCAM, covering a 7 arcmin field with 0.41 arcsec pixels. The HRCam observations cover a 2.5 arcmin field, with 0.11 arcsec pixels. The images were taken with I and R band filters, and also a $\sim 75\text{\AA}$ passband narrow-band (NB) filter at the wavelength of [O II] 3727Å at the redshift of the QSO. This dataset allows us to measure broad-band colours from blue-UV rest wavelengths at the QSO redshift, and to identify candidates for emission-line companions to the QSO. We can also make comparisons between the galaxies near the QSO and in the field. Table 1 lists the objects observed and the data obtained. The data were taken in two nights, and towards the end of one of them the sky brightness increased systematically with time due to scattered moonlight. There is no vignetting in the fields covered by the CCD.

Our analysis has three aspects. First, we compare the numbers of objects in the broad-band images near the QSO and over the field. Second, we compare the broad-band colours of objects near the QSO and elsewhere. Finally, we measure NB flux by comparing the NB and I band images, and compare these near and away from the QSO. In a few fields we obtained NB images with a filter not matched to the QSO redshift, as an empirical control. In all cases, we make comparisons between the field near the QSO and the rest of the image, using the same selection criteria and measurements. We rely to a lesser extent on absolute values of quantities, counts, and flux ratios, although we do comment on these and note whether they are reasonable.

In making this analysis, there are several basic concerns. These are: a) a detection criterion for faint objects; b) separation of stars and galaxies; c) measurement of magnitudes; d) self-consistency of procedures. In HCP the signal levels and accuracies of the data were described, but a more detailed account of the procedure is given here. The images were first processed with IRAF using standard procedures to incorporate sky and dome flat-fields and the photometric standard sequences. The FOCAS software was then used to locate and measure all objects on the frames. Obvious bright stars - compact sources ≥ 2 mag brighter than the QSO, which number about 20 per full field - were also rejected at this stage. In many cases, two images were taken with the I filter to assist in cosmic ray detection, but this was only partially successful in the automated search, particularly because the CCD was binned 2x2 (we were concerned with detection rather than spatial resolution, and the seeing did not warrant better sampling). In the end we found it necessary to inspect all images visually to ensure that cosmic rays, CCD cosmetic effects or other artifacts did not introduce spurious detections. The NB images do not go as deep as the R and I images, so only objects found by FOCAS on the wide band images were retained for the statistical analyses. Given the faintness of the objects and the rather poor sampling/seeing, no attempt was made to differentiate between faint stars and galaxies, so that the stars are a constant background for all fields. Thus the final object counts were those found by FOCAS, less those which are clearly artifacts and those which did not meet the 3σ criterion. The fluxes of objects were measured with FOCAS, DAOPHOT, and the IRAF task Rimexam. Because of variable crowding and image flaws only the Rimexam results have been used. For this program, various object apertures and background annuli were tried to determine optimal values, and noise statistics were

derived using matching apertures on many regions of blank sky. In normal cases the aperture was 8 arcsec. The entire process was done independently by two of us and comparison of the results show good agreement in all cases.

The detection limit for faint objects depends on the brightness, size (i.e. mean signal level per pixel), image quality, and sky signal. In our data, more compact objects are detected to fainter limits: in the case of faint galaxies, we reached objects somewhat fainter than 23. Since the main goal of our work was to determine whether or not there are excesses of faint galaxies near the quasars, and, if so, what their overall properties are, restricting the analysis to a sample complete to some limit is not necessary. The main requirement is one of uniformity of detection over an entire field. Utmost care was taken in this regard, and all objects counted and measured are 3σ or higher detections, and our numbers are self-consistent within each frame. We do not claim that we are detecting all, or even a known fraction of galaxies present: we do claim that we can compare the immediate environment of the QSO with the rest of the frame. Similarly, the colors and NB fluxes can be compared in the same internally consistent way. Thus, *the comparison of the QSO immediate environment with the whole frame is based on a self-consistent procedure for each field.*

As mentioned above, scattered moonlight affected a portion of the data and this obviously affects the detectability of faint galaxies. The number of ‘background’ galaxies counted in the frames correlates well with the sky brightness, as shown in Figure 1. In the cases of higher sky signal, we have used Figure 1 to scale the results to intercompare fields. These corrections are significant for 4 of our 12 $z=1.1$ fields (5 of 14 QSOs). Naturally, the object statistics within every image stand on their own in assessing any excess near the QSO. Our background galaxy counts are consistent with the those reported by Metcalfe et al (1991).

Our procedure was to catalog all detected objects in the 400 arcsec field, and to bin them in 16 100 arcsec subfields. In addition, a 100 arcsec subfield was centred on the QSO. The background counts are taken as the mean of the subfield counts that do not overlap the QSO subfield (i.e. normally 12). In some instances (typically 1 or less per 400 arcsec field) there are subfields that have 3σ excess counts over the mean. These are presumed to be distant clusters and are rejected from the background mean quoted in Table 2. (However, if they are included, the background count is raised by only 1 and we do not lose the overall significance of the excess in the QSO subfields. If the high values are not real clusters, then it follows that about 1 of our QSO subfield excess counts may also not be real.) The spread of the subfield source counts is used to estimate the uncertainty in the background value. Typically, this is within one of the square root of the object counts, so that the scatter is approximately gaussian. Similarly in the QSO subfields, the scatter of source counts by different authors or methods is slightly less than the square root of the number. The significance values of the excess counts given in Table 2 are derived from these two uncertainties. Table 2 also includes the results from HCP in which counts were made on the co-added I and R images. The present work kept the images separate in order to retain more colour information.

To compare the galaxies near the QSO and in the field, we measured the fluxes for all counted galaxies in the QSO subfields and also in one or more typical background subfields. In the frames free of moonlight, the photometry is good to ~ 0.2 mag at $I=23$, improving to half that scatter at 21 mag and brighter. The NB-I scatter is ± 1 mag at $I=23$, ± 0.5 mag at $I=22$, ± 0.25 at $I=20$ at the 3σ level. The measures were made in the same way in the NB images. Because of the weaker NB signal, these have faint limits about 0.7 brighter.

In addition to source counts, broad-band colours and the ratio of NB to I band fluxes were compared between the background and QSO subfields, to determine if there are differences. Plots of NB-R with I were used, as in HCP, to find objects which lie more than 3σ away from the expected measuring scatter: those with high NB fluxes are discussed as line emission candidates, and numbers compared with the background fields.

With $H_0=100$ and $q_0 = 0.5$ the box size is ~ 500 Kpc at $z=1.1$. We describe below the details of the individual fields, and then discuss the significance and implications of the results. We describe the results for the first field in more detail, as the process is similar for all.

2. RESULTS FOR INDIVIDUAL FIELDS

1336.8+2848 and 1336.8+2834

These two quasars are close together and at very similar redshift (1.124 and 1.113). Thus we could

observe them both in the same CCD frame, and use the same NB filter for both redshifts. The redshifted 3727Å wavelengths are 7916Å and 7875Å, and the filter centre was at 7906Å. The filter passband has a FWHM of 130Å and has a flat peak, so that the $z=1.113$ object(s) should have only slightly (if at all) weaker detections than the $z=1.124$. In addition, a control filter at 8096Å was used on the same field, which should not detect any QSO-redshift companions.

The R and I band images were divided into 16 100-arcsec squares and counts made of faint galaxies in all, as described above. Flux measures were made on the objects in both QSO subfields and for background comparison on two other subfields which fill the space between the quasars.

The results fairly strongly indicate an excess of faint galaxies around the quasars. This excess consists largely of blue galaxies and objects with excess flux in the narrow-band passband. These objects are not seen away from the quasars, and there is no population of emission-line candidates near the QSOs in the control filter image. We give the details in Table 2 and below.

In I band, the boxes that do not contain the quasars have an average of 26 ± 6 faint galaxies, while the quasar boxes have 45 and 41. The excess of 15 to 19 galaxies is significant at the $2.5 - 3\sigma$ level. In R band the figures are similar: background level of 26 ± 5 and quasar box counts of 51 and 45: excess of 24 and 19 at the $2.5 - 3.5\sigma$ level. The narrow band image counts are lower because of the weaker signal. The background is 16 ± 4 and the quasar boxes have 35 and 30 - a similarly significant excess. The subfield containing the QSO 1336.8+2848 has the higher counts in all cases.

In the plots of the R-I colours of objects in the quasar and field boxes (Fig 2), the field distribution is different at the 95% confidence level and the quasar boxes clearly have an excess of blue objects. The spatial distribution of the blue objects is shown in Fig 3: 1336.8+2848 is central in its group while 1336.8+2834 is nearer the edge. Using the criterion of $R-I < 1$ for blue objects, there are 75% and 64% in the QSO subfields, compared with 51% in the control fields.

Emission line candidates (Fig 4) differ between the quasar and control fields, and also between the correct and control NB filter images. In Figure 4 we show the mean N-I value for a featureless continuum object, and the 3σ scatter from the signal and noise levels in the data. We regard objects as emission-line candidates if they lie below the 3σ curve shown. Thus, the emission line strength required for detection increases as the object becomes fainter. In the control filter image, there is no population of emission line candidates anywhere, although the shorter exposure given means the scatter (shown in Fig 4) is larger. In the fields away from the quasars, there are 2 emission line candidates per 100 arcsec box, with the correct filter. In the quasar boxes with the right filter, there are 5 emission line candidates in each QSO 100 arcsec box. Of these, many are also very blue objects. Figure 5 (top) shows a colour-magnitude plot for the QSO and control subfields. The QSO subfield has more faint blue objects.

Thus, we conclude that there is an excess of blue *and* emission line objects in the QSO subfields. The emission line candidates overlap considerably with the blue objects, and the distribution of emission line candidates is similar to the blue objects. With so few objects and a sample that is incomplete at the faint end, it is not possible to make any statement about spatial structure that might relate to beaming of radiation from the quasars, or to reddening material. The emission-line candidates we do have, appear to cluster near the QSOs.

0850+140

This is a radio-loud QSO. The observed field appears to contain 2 clusters of faint galaxies. The QSO subfield has a 2.5σ excess of 14 faint galaxies, and a nearby field has an excess of 19 similar objects. The general background count rate is average at 25. The QSO subfield has 6 blue galaxies and a control field (not the other cluster) has 5. The NB filter is centred at 7906Å and the redshifted wavelength for 3727Å is 7864Å, which is further than most from the NB passband centre. Apart from the QSO, neither field has any strong emission-line candidates: the QSO has 1 possible candidate and the control field has 2. The colour distributions of galaxies are not significantly different.

The group of faint galaxies near the QSO is quite compact, with the QSO at one edge of it (Fig 6). The overall size of this region of faint galaxies is 30 x 70 arcsec, or 150 x 350 Kpc at the QSO redshift.

1335.3+2833

This QSO field does not have a clear result. We have 26 objects in the QSO field and 27 in the control field. Compared with all subfields, the QSO subfield galaxy counts have an excess of 5 (1σ) in I, and of 3 (1σ) in NB. The R image shows excess of 9 which is $2.5\text{--}3\sigma$. Visual inspection of the image suggests that if there is an excess of faint galaxies it is in a larger elongated region running diagonally through the subfield.

The colour plots for the QSO and control subfields are almost identical, and neither one has anything very blue. The QSO is the bluest object in either field. The next bluest objects occur equally in both fields and show no spatial placing of interest. The NB-I plots are also the same for each, and neither has any good candidates.

The analysis was repeated for another subfield with fewer galaxies. The result is very similar, with the same distribution of colours, and much the same spread of NB/I. In the latter there are slightly fewer objects on the NB signal side of the spread, but there is nothing which lies outside the expected scatter.

1336.2+2830

The number counts show no excess in the QSO field. The whole field has high sky brightness and somewhat low galaxy counts at 19 and 15 in I and R resp. The QSO does have a group of very faint galaxies while most other fields have brighter ones (Fig 6). There is a definite cluster of brighter faint galaxies (37 and 30) in one box away from the QSO. The QSO box has one blue galaxy and an average colour slightly bluer than the control fields. There are no blue galaxies in the control fields (which do not include the rich cluster).

There is one emission line candidate in the QSO field and none in the control fields. Of the galaxies in the QSO field, 5 of 11 lie on the ‘emission’ line side of the plot and none on the other: the control fields galaxies are evenly spread.

Overall, there is marginal evidence for a sparse, faint group associated with the QSO. The higher than average sky brightness causes the formal galaxy count excess to be zero, however.

1337.4+2744

This QSO has a small excess of galaxies in its box (4 or 1σ) above the mean of 17 in I and 13 in R. The NB image has an excess (also 1σ) of 2 above a mean of 8. The immediate vicinity of the QSO does not have a small group of galaxies. A correction for higher sky brightness had to be applied for this field, so the faintest galaxies will be missed.

However, the colours of the nearby galaxies are bluer than in the control field. There are 5 (of 21) galaxies bluer than the QSO, all of them faint. These are grouped in a line extending either side of the QSO (Fig 6). The control field has no blue galaxies at all.

The NB ratios show 3 emission line candidates (of 10, including the QSO: Fig 5), two of which are among the blue ones (the other 3 blue ones have no NB measure). These lie along the line defined by the blue galaxies. The control field has no emission line candidates in 4 measurable galaxies.

The results are consistent with a sparse group of faint blue galaxies around the QSO along a line on either side (Fig 5). The correction for sky brightness increases the excess count from 4 to 7 (Table 2).

1339.5+2738 and 1339.8+2741

These quasars have redshift of 1.175 and 1.185 respectively, and are in the same CCD field. They were observed with the 8096Å filter, and the redshifted 3727Å wavelengths are 8106Å and 8143Å. 1339.8+2741 is further from the filter bandpass centre but is within the filter FWHM (8034–8159Å).

The results in this field are not as clear, and suffer from high sky brightness. The faint galaxy counts in the two QSO fields are 18 and 17 in R and 18 and 20 in I, compared with 11 ± 2 in R and 11 ± 3 in I, in typical subfields. Thus there is an excess of about 7 in each QSO field, which has $2\text{--}3\sigma$ significance. While the I and R bands are not totally independent, we note that a similar excess is found in both. The counts in the NB images similarly give an excess of 2σ and 3σ in the QSO fields. The correction for sky brightness raises the excess to about 20 for each of these QSOs. We conclude that the QSOs are at least in small groups of galaxies. The distribution of the observed galaxies around the QSOs is tight in these cases too, with several lying within 10 arcsec radius (50 Kpc at the QSO).

The colours of the galaxies in the QSO and control fields are not different, and there are few blue objects ($R-I < -1$). The QSOs are both blue; 1339.5+2738 has two others and 1339.8+2741 has one other in their fields. A typical field has 3 blue galaxies.

The plots of I vs $NB-I$ are similar for all subfields, with no candidates for emission-lines, including the QSOs themselves (Fig 5). The scatter of points is symmetrical as we would expect for no emission line sources, and lies nicely within the expected scatter for a null result.

1632+391

This was observed on a later run, with the same filters and HR Cam. The field is smaller, the sampling different, and the exposures a little different. The field was divided into 4 sections, one surrounding the QSO. The galaxy counts were 18 for the QSO subfield and 20 in the diagonally opposite field, of generally fainter galaxies. The other two subfields have 6 and 8 galaxies. The QSO field has a tight group of irregular galaxies near the QSO, and also has an excess of blue galaxies grouped near the QSO.

There are no strong emission line candidates in either the QSO or control subfields. Of 6 moderate emission-line candidates, 3 are close to the QSO. Only one is blue. Of the 11 nearest neighbours of the QSO, 6 are as blue as or bluer than the QSO, and 3 others are emission-line candidates.

In this field, the data suggest a compact blue cluster associated with the QSO, although a wider overall field would have been useful to improve the galaxy count statistics. The better sampling and resolution of HR Cam however, allow us to note the structure and size of the QSO companions. The galaxies are shown in Figures 7 and 8. They are all irregular-shaped and have luminosity scale lengths of 4-5 Kpc at redshift 1.1. Their overall diameters to 1% of the sky ($\sim 26 \text{ mag/arcsec}^2$) are about 13 Kpc at redshift 1.1. Many of them also have low central brightness. Thus these are not symmetrical and standard galaxies.

1335.2+2685, 1336.2+2689, 1339.4+2756

These QSO fields were summarized in HCP, and Table 2 gives the measured quantities for them. They all contain a significant excess of faint galaxies in the QSO subfield, and of blue galaxies and emission line candidates. The sky signal is low and the faint galaxy detections are good. Figure 6 shows the distribution of blue and emission-line candidate galaxies in the QSO subfields. In all these we do not see a clear area of higher galaxy counts but there are usually several faint galaxies close to the QSO, and statistically the whole subfields have an excess of blue and emission-line objects. These counts reach the faintest limits in the dataset: applying brighter detection limits reduces the numbers but does not alter the overall excesses we find in the deeper sample.

3. DISCUSSION

In several instances (9 of 14) we see a significant (3σ) excess of galaxies associated spatially with the QSO. In most individual cases, and cumulatively, the QSO environments contain a small excess of blue galaxies ($R-I < -1$) and emission-line candidates compared with the field. In all fields combined, there is an excess of 155 objects in the QSO subfields compared with the other subfields, and this is significant at $> 5\sigma$ level.

While the field is known to contain faint blue galaxies at lower redshift, the association of galaxies this blue with the QSO at $z=1.1$ implies a very young population. Further, there are several more emission-line candidates near the QSO than in the field, also suggesting a population with active star-formation. The combined weight of these independent indicators suggests that several of the QSOs in our program do lie in groups of what may be very young galaxies.

At a redshift of 1.1 for $H_0=100$ and $q_0=0.5$ the distance modulus is 43.7. The k-corrections for an old population are 0.8mag in I and 1.5mag in R (see also Metcalfe et al 1991; Coleman, Wu, and Weedman 1980). As in HCP, we calculate for a starburst population, these are -1.9mag and -1.1mag respectively. Thus, a $I=22$ or $R=23$ galaxy at this redshift has absolute magnitude in these bands of -22.4 for an old population; -19.6 for a starburst; and -20.9 for an E+A population. Objects at this redshift with $R-I < -1$ must be starbursts. If we are observing a real population of galaxies associated with the QSOs, the blue ones are star-forming galaxies which may be of luminosity comparable with the LMC - i.e. of moderate to

low mass. We note that the negative k-correction for very young stellar populations at this redshift make such galaxies brighter by up to 2 magnitudes: the colours and brightness thus indicate strong evolution of such QSO companion galaxies.

The QSO-associated groups are compact and the galaxies are small. It is possible that we are seeing galaxy formation in small groups at this redshift. At low (<0.5) redshift, radio-loud QSOs lie in larger and fairly rich clusters (e.g. Yee and Ellingson 1993), while radio-quiet QSO have no more than 6 or 8 companions, and often fewer. Thus, the fact that groups such as we see at $z=1.1$ are not seen around QSOs at low redshift indicates that these clusters evolve significantly in the time interval since $z=1.1$. The elapsed time from $z=1.1$ to 0.5 is about 2.5 Gy, which considerably exceeds the lifetime for an individual QSO. Thus, the different environment of lower redshift QSOs implies that the site of QSO activity changes in this interval. In addition, the compact nature of the clusters, the small size and low mass of the galaxies themselves, may mean that they fade and perhaps merge into fewer galaxies which would be seen as small groups at lower redshift epochs, if we were to come across them. We also note that the evolution of a starburst would cause fading by 1 - 2 visible magnitudes in a relatively short time, and faster than the k-correction changes with decreasing redshift. Thus, they would become less easily visible as they evolve.

As an empirical experiment, we artificially redshifted the image of a $z=0.2$ cluster (Abell 2390) to $z=1.1$. This was done by altering the sky signal and noise to mimic the redshift-fading, and changing the pixel scale appropriately. The redshifted $z=0.2$ cluster did not resemble the groups we see here: at $z=1.1$, A2390 is considerably larger and less centrally concentrated. The brightest galaxies also appear larger and more regular. It is noticeable how many faint galaxies simply disappear: it is clearly desirable to have fainter detection limits and dark sky for further work. Nevertheless, it seems clear we are not seeing the equivalent of $z=0.2$ Abell clusters, at $z=1.1$.

There is no large difference between the radio-loud and radio-quiet QSO environments in our small sample. However, the radio-loud QSOs do appear to be in richer cluster environments on average, than the radio-quiet. Disregarding (or correcting) the high background fields, the excess counts in the QSO subfields range from 7 to 25, with one subfield showing no measured excess. The colours of the faint galaxies in the QSO subfields and the numbers of emission-line candidates generally support the conclusion that the QSOs are in groups or clusters of star-forming galaxies. These groups are compact compared with recent epoch clusters and the galaxies themselves are irregular and compact.

In conclusion, then, it appears that the environment of many, if not all, QSOs may evolve significantly between redshift 1.1 and 0.6 and lower. Since the lifetime of individual QSOs is considered to be less than the time between these epochs (from considerations of the radio structures, for example), this means that the site of QSO activity changes with epoch. In addition, the clusters we see at redshift 1.1 will evolve passively and by merging, and will not be seen in this form in the present day universe. Clearly, it is of value to study the QSO environment at other redshifts, and also to obtain spectra of the $z=1.1$ companions to understand their composition, state of star-formation, and dynamics.

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Figure captions

1. The number of faint galaxies per 100 arcsec subfield in R and I bands, as a function of sky signal level. Dashed curve is function used for correction.
2. Histograms of R-I for faint galaxies in QSO subfields and control subfield from Figure 3. The QSO subfields have a larger fraction of blue ($R-I < 1$) galaxies.
3. Distribution of galaxies in subfields in double QSO field. Circles have radius 1 arcmin centred on QSOs.
4. NB colour-magnitude diagrams for double QSO subfields. The horizontal line is the value for flat continuum with no emission line, and the curved lines are the 3σ scatter expected for the images. Emission-line candidates lie below the lower curved line. The QSOs are marked as asterisks. The lower panel is from both QSO subfields combined, with the control NB filter.
5. Top: colour-magnitude diagram for double QSO field. QSO subfields have more faint blue galaxies than control subfields. Lower: NB colour-magnitude plots as in Figure 4.
6. The distribution of faint objects in 6 QSO subfields, showing blue and emission-line candidate objects.
7. Galaxies in the neighbourhood of 1632+391, taken with HR Cam and 0.6 arcsec seeing. The QSO is the brightest object.
8. Contour plots of galaxies close to 1632+391. All objects shown are significant detections. Note the irregular and compact shapes. The QSO is the bright object in the upper right.

Table 2. Galaxy count statistics

Name	z	R	I	NB	Corr XS ^b	#Blue ^c	#Emis ^d
0834+250 field	1.122*		50-31=19(3 σ) ^a		18	17/55=.31 (1) 6/21=.29	18 4
0850+140 field	1.110*		39-25=14(3 σ)		17	9/22=.41 (1) 5/13=.38	0 0
1335.2+2685 field	1.090		43-31=12(2 σ)		12	33/48=.69 (8) 10/19=.53	4 0
1335.3+2833 field	1.124	24-15=9(3 σ)	26-21=5(1 σ)	16-13-3(1 σ)	12	18/24=.75 (0) 12/15=.80	0 0
1335.8+2834 field	1.086		43-25=17(3 σ)		20	16/33=.48 (3) 13/34=.38	8 0
1336.2+2689 field	1.088		40-30=10(3 σ)		10	15/23=.65 (6) 6/15=.40	4 3
1336.2+2830 field	1.116	13-15=-2	19-19=0	10-10=0	0	11/13=.85 (0) 18/22=.82	1 0
1336.8+2848	1.124	51-26=25(3 σ)	45-26=19(3 σ)	35-15=20(3 σ)	25	27/36=.75 (9)	5
1336.8+2834 field	1.113	45-26=19(3 σ)	41-26=15(2 σ)	34-15=19(3 σ)	20	21/33=.64 (4) 24/47=.51	5 2
1337.4+2744 field	1.120	16-13=3(1 σ)	21-17=4(1 σ)	10-8=2(1 σ)	7	11/16=.69 (5) 5/13=.38	3 0
1339.4+2756	1.095		41-33=8(3 σ)		7	12/24=.50	5
1339.5+2738	1.175	18-11=7(2 σ)	18-11=7(2 σ)	13-7=6(2 σ)	19	18/31=.58 (-3)	0
1339.8+2741 field	1.185	17=11=6(2 σ)	20-11=9(2 σ)	16-7(3 σ)	20	12/18=.67	
1632+391 field	1.082*	21-9=12(3 σ)	18-7=11(3 σ)	9-6=3(1 σ)	(28)	14/21=.67 (4) 6/13=.46	3 1

* = Radio-loud

^a Numbers in this column based on combined R and I images.

^b Galaxy excess corrected for sky brightness to background count rate of 30 per subfield

^c Number of galaxies with R-I<1 / total in subfield, not corrected for sky brightness. (Numbers in parentheses are excess of blue objects in QSO subfield.)

^d Emission-line candidate objects outside 3 σ scatter, not corrected for sky brightness.